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(54) IMPROVEMENTS IN AND RELATING TO CLAD WIRE ELECTRIC CONDUCTORS

(71) We, MATSUSHITA ELECTRIC INDUSTRIAL COMPANY LIMITED, a Japanese Company, of 1006 Kadoma, Osaka 571, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to clad wire electric conductors, and more particularly to conductors suitable for use in the production of electric contacts, comprising a base metal with a surface layer of noble metal firmly bonded to the base metal.

The invention includes a method of making a clad wire electric conductor which comprises providing a strip including at least a base metal and at least a surface layer of noble metal bonded to said base metal, forming said strip into a transversely arcuate form with the noble metal on the convex surface and drawing said formed strip through a die to provide a wire which is partially clad with a noble metal.

Clad conductors can be made by electrodeposition methods by sheathing but these methods have practical disadvantages. The invention makes possible the production of clad conductors, which may have two, three or more layers, by an improved method, in which the layers are bonded firmly to each other and thickness of each layer is variable as desired.

Objects and advantages of the invention will be apparent from the following description of embodiments thereof, given by way of example, and the accompanying drawings wherein:—

Figures 1*a* to 1*d* are diagrammatic cross-sectional views of successive stages of a conductor in the course of producing a contact material; and

Figures 2*a* to 2*e* are similar cross-sectional views, of a conductor in making a contact material, by another process.

In the processes of making a material for electric contacts described hereinafter, there is first provided a composite metal strip of substantial length which includes at least a base metal and at least a surface layer of a noble metal: this strip is softened by annealing and is then formed to give it an arcuate shape in cross-sectional form with the noble metal surface on the convex surface.

This strip is then drawn, by means of a suitable die so as to provide a composite contact material in a substantial length. The material can be further annealed as necessary. For convenience, the elongated material obtained after drawing the strip will be hereinafter referred to as wire.

In carrying out this process, the noble metal surface layer is extended transversely in the first forming step, and the following drawing process provides a clad wire having a noble metal layer being extended round more than half the periphery of the wire. If the first forming step is omitted, the noble metal layer is compressed laterally in the drawing process and the layer on the clad wire is reduced in width, which is undesirable as it may cause poor contact characteristics.

Clad sheet or strip can be made easily and cheaply and with good bonding between the layers, so that when the strip is formed as described, the incidence of bonding failures between the layers is reduced.

Clad wires comprising two or more clad layers can be easily provided, by using suitable multiple layer starting strip.

The thickness of the layers and the base of the initial strip can be widely varied when the strip is being made. Figure 1 is a series of diagrammatic cross-sectional views, Figures 1*a* to 1*d* showing changes in the cross-section of the material at successive steps in the course of fabrication. The starting material is shown at Figure 1*a* and consists of a strip 10 of composite material, comprising a base layer 11, an intermediate layer 12 and a noble metal surface layer 13. The strip of composite material is obtained by slitting a wide sheet of the composite material. Such a sheet of material can be made in known manner; it is advantageous that it is possible to get very good bonding of metal layers in sheet form.

The clad strip 10 is annealed in a non-oxidising atmosphere at a temperature above the recrystallization temperature or temperatures of the component materials. After being annealed for a period of time which depends upon factors including the dimensions of the strip, the strip is cold-drawn through a forming die 14. The drawn material 20 is of modified cross-sectional shape and is of generally circularly arcuate; the radial thickness is substantially equal to the thickness of the clad strip before drawing, and with a circular arc length which is substantially equal to the width of the strip and as shown in Figure 1*b*, the noble metal layer 13 is on the outside or convex side of the modified strip 20. Thus, the flat clad strip 10 is converted to the formed clad strip 20 having a general cross-sectional form which is circularly arcuate in a direction at right angles to the length of the strip, which is the drawing direction.

The formed clad strip 20 is again cold-drawn through a die 15 having a die opening which is of semicircular or half-round section, so that the curvature of the clad strip is increased. In the resulting composite strip 30: at this stage the base metal layer 11 presents a longitudinal groove 16 as shown in Figure 1*c*.

The material is then successively reduced by passing it through a series of dies of successively smaller cross-section. In these step by step reductions the groove 16 is progressively reduced in size and eventually disappears, leaving a wire 40 clad as shown in Figure 1*d*.

Figures 2*a* to 2*e* show the steps of another process which is similar to that described with reference to Figure 1, but the initial strip in Figure 2 comprises two layers only: the noble metal surface layer 13 and the base metal layer 11. Also, forming of the strip is carried out by means of a pair of forming rolls comprising a concave top roll 17 and a corresponding convex lower roll. The strip 60 after passing through the rolls has a profile which is substantially arcuate, and the noble metal layer 13 is again on the convex surface.

The strip 60, after passing between the shaping rolls is passed through a die 19, Figure 2*c*, the opening of which is circular in cross-section. As a result the strip is further modified in shape and assumes a shape somewhat as indicated at 70 in Figure 2*c*. Part of its periphery is brought to circular form, but as with the process of Figure 1, the longitudinal groove 16 is formed in the emergent material.

The material is passed through further dies, also of circular cross-section, reducing both the diameter of the drawn wire and the dimension of groove 16 as at 80 until finally a wire of circular cross-section, with noble metal cladding over part of its periphery is obtained as at 90 in Figure 2*e*.

The noble metals which can be used for the surface layer 13 include silver, silver alloys, gold, gold alloys, palladium, palladium alloys, platinum and platinum alloys, depending upon the electric characteristics of the contact which are required. The intermediate layer 12 can be silver, silver alloy, nickel and nickel alloy depending upon the desired conductivity or diffusion barrier or bonding characteristics. The base metal layer can be of copper, copper alloy, nickel or nickel alloy, chosen principally for its mechanical properties.

The extent of the noble metal surface around the periphery of the clad wire, is affected by the ratio of the thickness of the metal strip to its width. For this reason, it is preferable if this ratio lies between 1/3 to 1/5. If a thick strip is used having a ratio in excess of 1/3 it is difficult to form the strip appropriately in the first step. If a wide strip is used with a ratio less than 1/5 the groove 16 which is formed becomes unduly deep and may lead to degradation of the mechanical properties of the clad wire.

To bend the strip sufficiently in the forming operation, it is preferable to carry out the forming step in two or three steps increasing the bending of the strip at each step until it has the desired cross-sectional shape before it is drawn.

The annealing of the strip to soften it before bending is carried out in a non-oxidising atmosphere, as may be necessary such as nitrogen, gas, argon gas or in vacuum to prevent oxidisation of the material.

The reduction of the cross-sectional area of the material in cold-drawing varies from 15% to 30% per pass. Various lubricants, such as mineral oil, fat oil, or soap, are applied at the die to reduce the power required for drawing and to improve the surface finish of the drawn material and to increase the life of the die. The drawing speed

may vary, depending on conditions and may be, for example, 5 to 50 m/min, the drawing speed is affected by the cross-sectional areas of the material and also by the temperature developed in drawing which affects the properties of lubricant, the structure of the drawn metal and the life of the die.

Although the wires shown in Figures 1 and 2 are semicircular and circular respectively, in cross-section other shapes of wires, such as triangular, square, trapezoidal or other special shapes, may be obtained by employing dies of appropriate cross-section.

Table 1 sets out examples of materials and Table 2 the fabrication conditions and properties of the wires obtained in the Table, the symbols used have the following meanings:

D: degree of reduction of the area after final annealing,
ϕ: diameter,
R: radius,
σ: untimate tensile strength in tension,
δ: elongation,
Hv: Vickers hardness of the surface layer under a load of 25 g; this hardness is affected by hardness of the under layer as the top layer becomes thinner.

TABLE 1

Example	Width (mm)	thickness (mm)	metal of each layer		
			surface layer (wt%)	intermediate layer (wt%)	base layer (wt%)
1	2.8	0.6	Ag	—	phosphor bronze
2	2.8	0.6	Au	66Ni–34Cu	phosphor bronze
3	2.5	0.5	Pt	—	Ni
4	7	2	60Ag–40Pd	Ni	phosphor bronze
5	4.5	1	30Ag–40Pd–30Cu	Ni	copper-beryllium
6	4.5	1	30Ag–40Pd–30Cu	Ni	phosphor bronze
7	7	2	70Au–27Ag–3Ni	Ni	phosphor bronze
8	2.8	0.6	70Au–27Ag–3Ni	95Ag–5Cu	phosphor bronze
9	7	2	85Pd–12Ag–3Ni	85Ag–13Cu–2Ni	66Ni–34Cu

TABLE 2

Example	Condition of fabrication			Finished clad wire						
	Forming	Annealing temperature (°C)	D (%)	Cross-section	Dimension of cross-section (mm)	thickness (µ) top layer	thickness (µ) intermediate layer	(µ) (kg/mm²)	δ (%)	Hv
1	die	500	70	round	2R 0.75	10	–	102	<5	120
2	die	650	60	semi-round	R 0.3	3	12	98	<5	240
3	die	650	20	triangle	Side 0.3	2	–	75	28	130
4	roll	650	55	semi-round	R 0.5	4	7.5	92	<5	241
5	die	700	40	semi-round	R 0.3	10	10	110	<5	390
6	die	(aging 350°C)	40	semi-round	R 0.5	20	5	60	8	390
7	roll	650	55	tropezoid	Top 0.5	4	7.5	92	<5	225
8	die	500	70	semi-round	R 0.3	4	38	98	<5	160
9	roll	650	55	semi-round	R 0.3	3	12	82	<5	170

WHAT WE CLAIM IS:—

1. A method of making a clad wire electric conductor which comprises providing a strip including at least a base metal and at least a surface layer of noble metal bonded to said base metal, forming said strip into a transversely arcuate form with the noble metal on the convex surface and drawing said formed strip through a die to provide a wire which is partially clad with noble metal.

2. A method according to claim 1, wherein said strip has a ratio of thickness to width which lies within the range from 1/3 to 1/5.

3. A method according to either of the preceding claims, wherein said strip is brought to arcuate form by being drawn through a forming die.

4. A method according to either claim 1 or claim 2, wherein said strip is brought to arcuate form by being passed between forming rolls.

5. A method according to any of the preceding claims wherein the clad wire is of round, semicircular, triangular, rectangular or trapezoidal in cross section.

6. A method according to any of the preceding claims wherein said noble metal surface layer extends around at least half the periphery of the cross section of the clad wire.

7. A method according to any of the preceding claims, wherein the surface layer of the wire includes silver, silver alloy, gold, gold alloy, palladium, palladium alloy, platinum or platinum alloy.

8. A method according to any of the preceding claims, wherein the said base metal includes copper, copper alloys, nickel or nickel alloys.

9. A method according to any of the preceding claims, wherein said wire includes an intermediate layer.

10. A method according to claim 9, wherein said intermediate layer includes silver, silver alloy, nickel or nickel alloy.

11. A method of making a clad wire electric conductor substantially as herein described with reference to the accompanying drawings.

12. A wire made by a method in accordance with any of the preceding claims.

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1432906 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

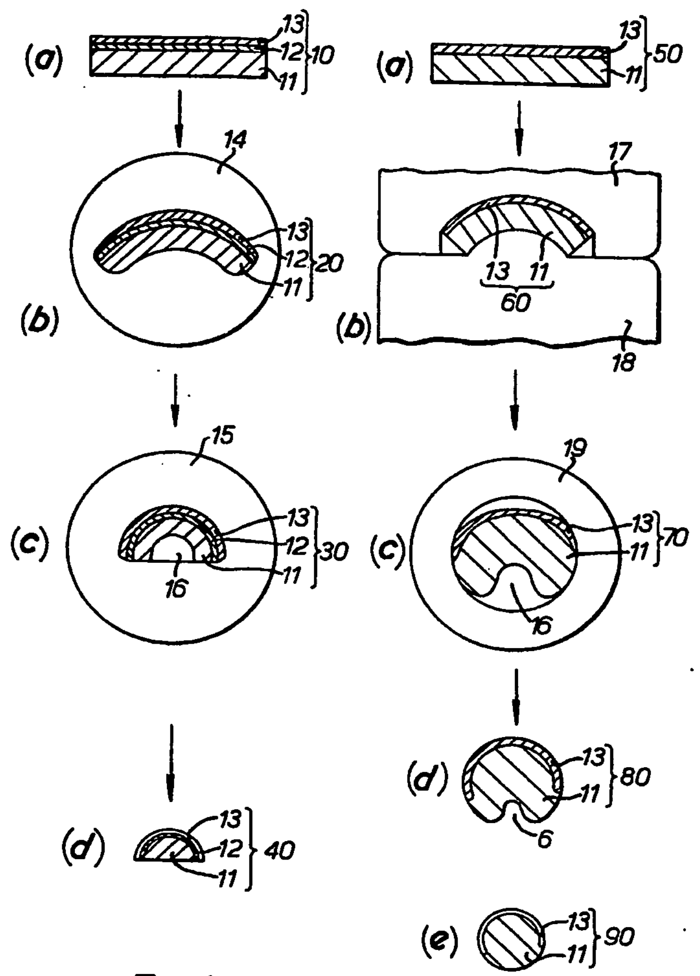

FIG. 1.

FIG. 2.